

PERIODICITIES WITHIN A FIXED-INTERVAL SESSION¹

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Within-session periodicities in number of responses per interval and postreinforcement pauses were investigated on fixed-interval schedules of 1, 2, and 3 minutes with rats. Postreinforcement pause values and the number of responses in successive intervals were not systematically related. The direction of change of these variables from one pair of intervals to the next revealed periodicities in that the direction of change varied more than would be expected by chance. A response prevention technique used to manipulate the length of time spent responding in an interval had little effect on the postreinforcement pause value of the next interval except when only a single response was permitted in an interval. This procedure tended to reduce the postreinforcement pause value of the next interval to an abnormally low level.

Key words: Fixed-interval schedules, postreinforcement pauses, number of responses per interval, sequential effects, autocorrelations, runs test, lever pressing, rats

In addition to generating the well-known within-interval pattern of responding (Dews, 1978; Schneider, 1969), the fixed-interval (FI) schedule may produce other response periodicities. For example, Zeiler and Davis (1978) found a systematic relation between the daily overall response rates in successive sessions at various FI values with pigeons. Individual day response rates were classified as being either above or below the mean for the whole FI condition. Daily sessions with response rates above this mean tended to cluster together sequentially, as did sessions with response rates below the mean.

Another type of response periodicity is the change in responding from one interval to the next within an FI session (Dews, 1970; Ferster & Skinner, 1957; Shull, 1971; Zeiler, 1977). Between-interval periodicities might occur because the value of some variable in one interval determined the value of that variable in the next interval. For example, Shull (1971) proposed that postreinforcement pause lengths in successive intervals vary such that a long pause in one interval tends to be followed by a short pause in the next. This type of effect

will be referred to as a *numerical periodicity*, since it is concerned with the relation between numerical measures of behavior in successive intervals. On the other hand, the direction of change of some variable may fluctuate from one pair of consecutive intervals to the next. For example, if interval $n + 1$ of a FI session contains more responses than interval n , interval $n + 2$ may contain fewer responses than interval $n + 1$, and so on. In this case, the direction of change of the variable is fluctuating systematically. This type of effect will be referred to as a *directional periodicity*. It is not concerned with the numerical values of successive observations except insofar as these define a directional change.

Ferster and Skinner (1957) presented evidence for numerical periodicities in the number of responses in successive intervals on FI 4- and 8-min, suggesting that the number of responses in successive intervals was inversely related. Dews (1970), on the other hand, found that the number of responses in successive intervals under FI 3-min tended to be positively related.

Shull (1971), in his study of numerical periodicities in postreinforcement pauses, proposed that the variable critically controlling such periodicities was the "work time," the length of time the subject spends responding in an interval, rather than, for example, the number of responses emitted. Shull manipu-

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lated work time with a complex procedure and found results consistent with this view.

The only previous report of directional periodicities within FI sessions is Dews' (1970) finding that the direction of change in the number of responses emitted between pairs of consecutive intervals fluctuated more than would be expected by chance.

All the above studies of response periodicities used pigeons; the present experiment investigated numerical and directional periodicities in both postreinforcement pauses and number of responses per interval on FI schedules of 1, 2, and 3-min with rats. In addition, a response prevention technique manipulated work time in some phases of the experiment.

METHOD

Subjects

Four male Sprague-Dawley albino rats, obtained from Charles River (U.K.) Ltd., were used. They were approximately 100 days old at the beginning of the experiment and were maintained at 80% of free-feeding weight throughout.

Apparatus

A Campden Instruments rodent test chamber (Model 410, 20.3 cm high, 23.8 cm wide, 22.9 cm deep) was equipped with a single Campden Instruments retractable lever (Model 446) in the left lever aperture. The houselight was continuously illuminated. Reinforcement consisted in the delivery of a single Campden Instruments 45-mg food pellet accompanied by a food-dispenser click and a brief illumination of the food tray. The chamber was enclosed in a sound- and light-attenuating housing, and all experimental events were controlled by a hybrid relay/solid-state logic system located in another room.

Procedure

Subjects were magazine and lever-press trained in the conventional manner. They were then allowed to obtain 300 reinforcers in two sessions. Each lever press was reinforced.

Phases 1, 3, and 5 consisted of FI training. The schedule was FI 1-min in Phase 1, FI 2-min in Phase 3, and FI 3-min in Phase 5. The first lever press of each day produced food and initiated the first FI interval of the session. Each session of Phase 1 contained 45

intervals; each session of Phases 3 and 5 contained 30 intervals. Phase 1 lasted for 20 sessions, Phase 3 for 24 sessions, and Phase 5 for 33 sessions. Subject R7 did not maintain responding during Phase 5 after about Session 25 in spite of previously responding readily, and was dropped from the experiment.

Phases 2 and 4 involved a response-prevention technique. The schedule in Phase 2 was FI 1-min, and that in Phase 4 was FI 2-min. In Phase 2 the first response of the day was reinforced, and this initiated an FI 1-min interval with the lever present throughout. Delivery of the next reinforcer initiated the following sequence. Two types of intervals ("Preceding" and "Following" intervals) alternated in strict succession. In Preceding intervals the lever was retracted from the chamber for a period of time (the enforced pause). At the end of the enforced pause, the lever was returned, and the first lever press occurring 1 min after the previous reinforcer was reinforced. This reinforcer initiated a Following interval—a normal FI 1-min interval with the lever present throughout. Reinforcement at the end of the Following interval initiated the next Preceding interval, and so on. In Phase 2 the enforced pause values used were 0, 10, 20, 30, 40, 50, and 60 sec. Each session involved 15 Preceding intervals with a constant enforced pause. The enforced pause value was altered in an unsystematic fashion every day, each rat going through a different arbitrary sequence. Seven sessions were required for Phase 2.

Phase 4 used an identical procedure except that the basic schedule was FI 2-min and the enforced pause values were 0, 20, 40, 60, 80, 100, and 120 sec. Phase 4 lasted for seven sessions.

Sessions were conducted daily, with occasional single-day breaks.

RESULTS

Table 1 shows aggregate means and standard deviations of postreinforcement pauses and number of responses per interval for the last three sessions of Phases 1, 3, and 5.

Numerical periodicities were evaluated using the autocorrelation (lag of 1) statistic (Weiss, Laties, Siegel, & Goldstein, 1966). This correlates values of some variable in successive pairs of elements in a time-ordered series. If

Table 1

Postreinforcement pause length per interval (mean and standard deviation in sec) and number of responses per interval (mean and standard deviation in responses) for last three sessions of Phases 1, 3, and 5.

Subject	FI (minutes)	Post-reinforcement pause		Responses per interval	
		Mean	Standard deviation	Mean	Standard deviation
R5	1	33.1	12.99	22.3	8.78
	2	71.0	23.16	36.1	15.80
	3	138.6	65.36	12.6	11.10
R6	1	15.2	15.90	22.5	8.54
	2	42.3	24.45	57.3	32.58
	3	99.9	50.43	48.3	34.37
R7	1	42.9	15.34	11.8	5.49
	2	65.0	25.52	18.4	12.38
R8	1	33.6	15.33	32.0	16.00
	2	52.8	25.77	115.6	44.95
	3	66.1	39.72	55.3	38.80

Table 2

Autocorrelation values derived from aggregate data for last 3 sessions on FI 1-, 2-, and 3-min. Individual session values are also shown.

Subject	FI (minutes)	Postreinforcement pauses		Responses per interval	
		Aggregate	Individual sessions	Aggregate	Individual sessions
R5	1	-.36	.19	-.19	-.03
			.06		-.02
			-.05		-.01
	2	-.15	.30	-.31	-.06
			-.20		-.06
			-.05		-.08
	3	.11	.18	.03	.11
			-.05		.00
			.01		.00
R6	1	.10	.30	-.03	-.10
			.00		.11
			.10		-.03
	2	-.26	-.05	-.09	.11
			.02		-.25
			-.25		.02
	3	-.03	-.06	-.08	-.10
			-.11		-.04
			.03		-.05
R7	1	.16	.18	-.04	-.18
			-.15		-.11
			-.24		-.03
	2	.13	.14	-.03	.01
			-.04		.01
			.20		-.05
R8	1	.01	-.16	.05	-.10
			-.22		.03
			.13		.04
	2	-.02	-.05	-.04	.00
			.11		-.04
			-.38		-.02
	3	-.08	-.16	.02	.15
			-.02		-.01
			.04		-.14

Table 3

Runs test analysis of data from last 3 sessions on FI 1, 2, and 3 min. Z-scores derived from aggregate data of last 3 sessions are shown. Data from individual sessions are indicated as significant at .05 or better (S) or nonsignificant (NS).

Subject	FI (minutes)	Postreinforcement pauses		Responses per interval	
		Aggregate	Individual sessions	Aggregate	Individual sessions
R5	1	4.8*	S	3.3*	NS
			S		S
			S		NS
	2	4.7*	S	4.8*	S
			S		NS
			S		S
	3	2.9*	NS	3.6*	S
			S		NS
			S		NS
R6	1	3.4*	NS	4.1*	S
			NS		NS
			S		S
	2	4.4*	S	3.7*	S
			NS		NS
			NS		S
	3	3.2*	S	4.8*	S
			S		S
			NS		S
R7	1	2.3*	NS	1.4	NS
			NS		NS
			NS		NS
	2	1.8	NS	3.5*	NS
			S		S
			NS		NS
R8	1	2.9*	NS	2.9*	S
			S		NS
			NS		NS
	2	3.1*	NS	3.3*	NS
			NS		NS
			S		NS
	3	3.4*	NS	4.0*	NS
			NS		NS
			S		NS

*Values significant at .05 or better.

these values are positively related, positive autocorrelations result; if they are inversely related, negative autocorrelations occur.

Table 2 shows autocorrelations for postreinforcement pauses in the last three sessions of Phases 1, 3, and 5. Neither individual session values nor those calculated on three-session aggregates were large or systematically negative or positive. Table 2 also shows analogous data for the number of responses per interval. The results were similar, with small autocorrelations of variable sign predominant.

Directional periodicities were evaluated using the runs test (Siegel, 1956). To apply this

test the raw data (e.g., postreinforcement pause values in individual intervals) were converted to a directional sequence. If the postreinforcement pause in interval $n + 1$ was greater than the pause in interval n , this was scored "plus"; if it was less, it was scored "minus." A similar transformation was applied to the data on the number of responses per interval. These sequences of pluses and minuses may be analyzed by a runs test to determine whether they are randomly ordered. Deviations from chance may be of two sorts: (a) fewer runs than chance (indicating in this case systematically increasing and decreasing

trends across consecutive pairs of intervals), or (b) more runs than chance (indicating that the direction of change between consecutive pairs of intervals tends to vary more than would be expected by chance).

The final result of a runs test on a large sample is a Z-score where positive Z values indicate more runs than chance and negative values indicate fewer. The result is significant at $p < .05$ if the absolute value of Z is 1.96 or more.

Table 3 shows Z-scores for data from the last three sessions of phases 1, 3, and 5 analyzed as a single large sample. All significant values are starred.

For small data samples, such as individual sessions, the Z approximation cannot be used. Siegel provides a method of estimating significance in these cases (Siegel, 1956, Table F), and this has been applied to runs data of individual sessions from the last three sessions of Phases 1, 3, and 5. Table 3 indicates whether run data from an individual session is significant ($p < .05$) or nonsignificant.

All three-day aggregate runs analyses (except two from R7) were significant and all Z-scores were positive, indicating more runs than chance. Individual session data showed a similar pattern with about half (postreinforcement pause data), or just more than one-third (number of responses per interval), of sessions reaching significance.

Data from Phases 2 and 4 are shown in Figures 1 and 2. Enforced pauses in Preceding intervals had little effect on the postreinforcement pauses in Following intervals, except possibly when the Preceding interval contained only 1 response.

DISCUSSION

The results of the present study provided little evidence of the kind of sequential effect proposed by Shull (1971). Autocorrelation coefficients, which would be expected to be strongly negative if pause values are related as Shull (1971) suggested, were generally negligible. Additionally, the number of responses emitted in one interval was not correlated with the number emitted in the next. Furthermore, direct manipulation of work time had little

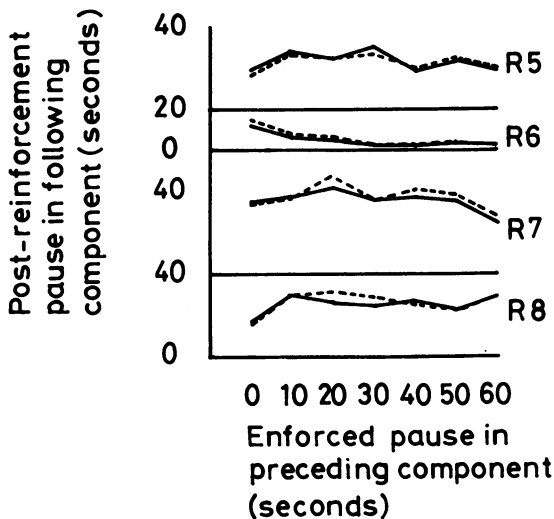


Fig. 1. Data from Phase 2. Solid lines connect mean postreinforcement pauses from sessions with enforced pause values shown along horizontal axis. Dotted lines connect medians.

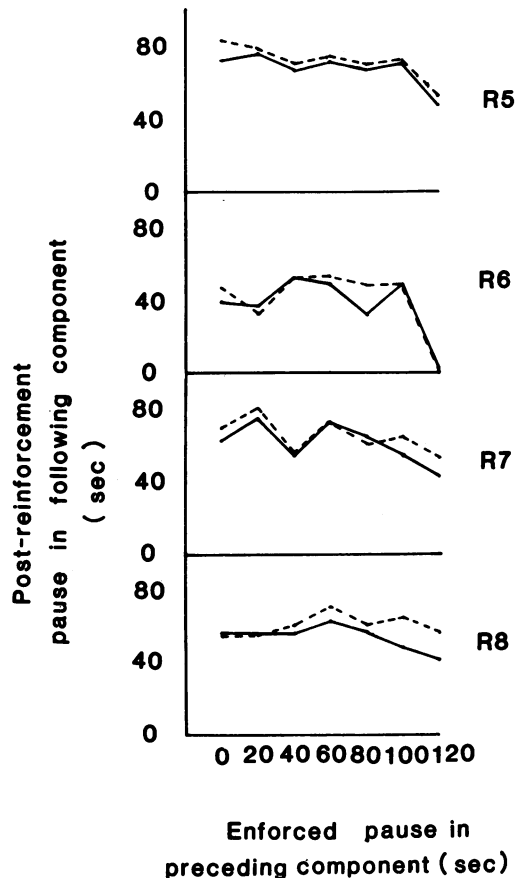


Fig. 2. Data from Phase 4. Solid lines connect mean postreinforcement pauses from sessions with enforced pause values shown along horizontal axis. Dotted lines connect medians.

effect, except when the enforced pause resulted in a single response occurring in an interval, in which case the postreinforcement pause of the next interval was reduced.

The above results argue strongly that, with rat subjects and the schedules used in the present study, the postreinforcement pause value of one interval is not an important determinant of the pause value of the next, and the number of responses in one interval does not directly determine the number of responses in the next interval.

On the other hand, strong evidence of directional periodicities was found. The direction of change of both postreinforcement pauses and number of responses did shift between consecutive pairs of intervals more than would be expected by chance, at all FI values used.

The directional periodicities found in response number in the present study are very similar to effects noted by Dews (1970) in the behavior of a pigeon on FI 3-min. The analysis in the present paper differs somewhat from that applied by Dews, but if Dews' data (from Dews, 1970, p. 55) are analyzed by the runs test, a significant directional periodicity ($Z = 4.4$, $p < .001$) is found. This suggests that directional periodicities in response number under FI schedules have cross-species generality.

Similarly, postreinforcement pause data from a pigeon subject on an FI 300-sec schedule presented by Shull (1971, p. 223) also show significant directional periodicities ($Z = 5.2$, $p < .001$) when analyzed by the runs test. It would seem that directional periodicities in pause length, such that the direction of change fluctuates more than would be expected by chance, also have cross-species generality.

Explanations of directional periodicities must remain speculative until further experi-

mental analysis is performed, but a number of possible causes of the kind of between-session effect observed by Zeiler and Davis (1978)—for example, physiological changes—seem less applicable to within-session effects.

The results of the present study, whatever their cause, are consistent with the emerging view (Zeiler, 1977; Zeiler & Davis, 1978) that one important effect of reinforcement schedules is the production of systematic response variability.

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